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INSTALLATION AND INITIAL TESTS OF LORAN-C AN/ARN-114 (XE-1) IN A U.S. FOREST SERVICE AIRCRAFT

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Abstract page #1

Abstract

The LORAN navigation set was installed in a USFS Aero Commander and tested for navigational accuracy. Navigational data from the system was not reliable during portions of the flight test due to minor installation faults and poor LORAN signal reception. Reliable navigational data was obtained at four of the eight checkpoints selected for the flight test. The system indicated aircraft position 10 to 320 meters from the checkpoints when actual aircraft position was over the checkpoints.

Work to rectify malfunctions and prepare the LORAN navigation system for operational use has been initiated.

INTRODUCTION

The navigational set, LORAN, AN/ARN-114 (XE-1) is intended for use in obtaining continuous present position display in LORAN time differences or UTM coordinates. The unit displays bearing and range to selected checkpoints, course traveled and ground speed, cross track error from a selected course and distance to the selected checkpoint. In addition, the unit provides signals to drive a course deviation indicator and range/valid flags on selected display.

OBJECTIVES

The purpose of these tests was to assure that the LORAN navigational set was in the proper working condition. Bench tests, installation of the system in the USFS Aero Commander, preflight tests and flight tests were conducted to determine if the system functioned properly and what additional measures would be needed to maintain the system in operating condition. These tests also provided a working introduction to the LORAN system for the USFS.

TEST CONDITIONS

Tests were conducted under three different conditions during the week of July 11-15, 1977.

Bench tests were conducted by Commander R. Wehr, USCG; A. Jasumbach, Project Leader, Missoula Equipment

Development Center; W. H. Clerke, Survey Improvement Specialist, Environmental Quality Evaluation; C. W. Dull, Entomologist, Aerial Survey Team; and D. W. Myler, Group Leader, Aviation Management Group. The bench tests were conducted in the Epps Avionics Laboratory at Peachtree-DeKalb Airport, Chamblee, Georgia. A LORAN navigation Test Set, AN/ARM-166 (XE-1), was used during the bench test. This test consists of a LORAN simulator, processor control/display (with self test functions), input/output, and a power supply. Utilizing the diagnostic programs stored in the memory and other features, the operator can manually simulate operational conditions to test the LORAN navigation set prior to installation in the aircraft.

Equipment Installation. Following the bench tests, the navigation set was installed in the USFS Aero Commander N194Z. A coaxial cable antenna was installed running from a point in the middle upper fuselage to the tip of the vertical stabilizer out to the tip of the right wing (Fig. 1).

A protective box was constructed to house the control indicator unit. It was installed below the auto pilot in the center of the console. In this position it is easily accessible to both pilot and co-pilot. A clear plastic shield was then hinged to the housing box to close over the display for protection of the control indicator box (Fig. 2).

Fig. 1. Coaxial cable antenna installed for LORAN reception.

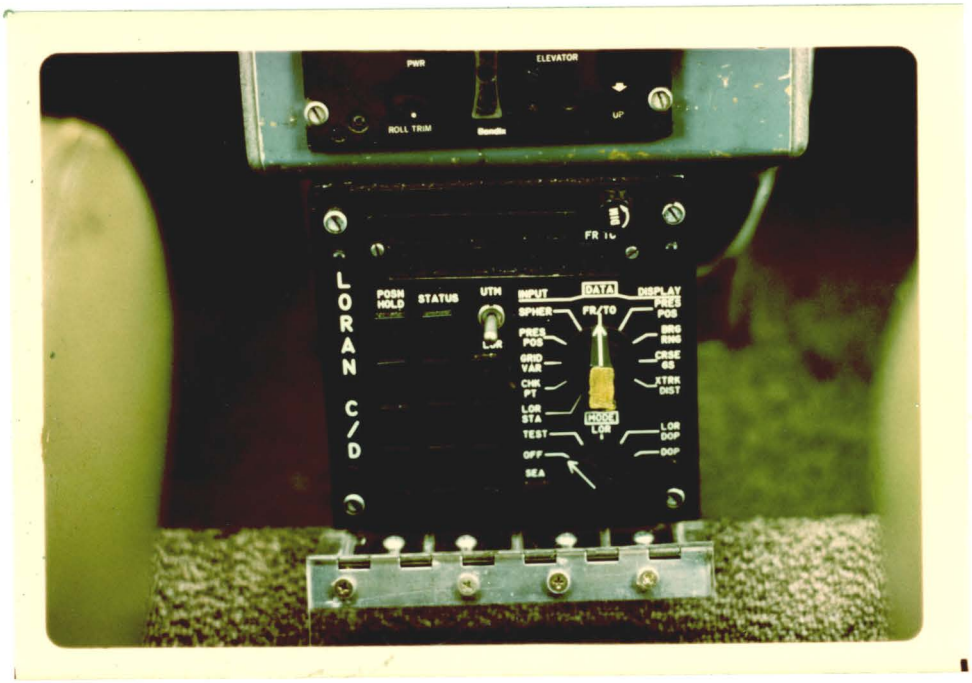

Fig. 2. Control Indicator Box with housing and protective shield.

The mounting base for the receiver/computer unit was placed in the aft section behind the baggage compartment where space for accessory oxygen tanks is allocated. The receiver/computer unit was then installed on the mounting base.

A necessary requirement for the proper installation of the antenna coupler is that it must be in a close proximity to the receiver/computer unit, this assures proper frequency reception. Therefore, it was installed next to the receiver/computer fixed to the skin of aircraft on the interior of the fuselage.

The electrical cables and connectors were installed to all units. Cabling from the receiver/computer to the control indicator unit was channeled along the right side of the cabin within the fuselage. The system was connected to the aircraft power supply. A cable carrying the output to drive the CDI (course deviation indicator) and flag on the panel was installed. A switch was installed to allow the CDI to be used for the LORAN or conventional VOR/DME navigation display.

Preflight Tests were conducted by Dull, Clerke and C. Morris (Pilot) at Peachtree-DeKalb Airport, Chamblee, Georgia, just prior to the flight test. The preflight and flight tests utilized existing LORAN east coast LORAN-C stations. Geographic coordinates for checkpoints

used in these tests were determined from USGS topographic maps for North Georgia and Alabama.

Flight Tests were conducted by Dull, Clerke and Morris. The navigation set remained in the LOR mode of operation throughout the flight. The test included clearly identifiable checkpoints chosen from USGS 1:250,000 scale maps from which the UTM coordinates could be determined. The pilot would indicate at which time the aircraft was directly over a checkpoint and the position hold on the control unit would be depressed. Data was recorded in UTM coordinates and time differences as the overfly was completed. While en route to each checkpoint, the indicated displays for bearing, range, course, ground speed, and distance were compared to the calculated data. The test pattern flown is presented in Figure 3.

Propagation anomaly corrections were recorded and entered as program data while en route, improving accuracy in overflight with each successive checkpoint. The aircraft was flown at an altitude of 1500 feet above the terrain at a ground speed of approximately 165 mph. Refer to Appendix I for an annotated checkoff list concerning the preflight and flight tests.

TESTS CONDUCTED

In each of three test conditions (bench, preflight, flight) the following tests were performed:

Self Test. The self test routine is performed to assure that the navigation set is operating properly and the interface between the other units is proper.

Controller Entry Tests. The controller entry tests were performed to evaluate the following functions:

(1) Entry of spheroid designator for UTM.

(2) Entry of present position in UTM coordinates.

(3) Entry of grid variation (magnetic variation) angle.

(4) Checkpoint(s) entry.

Signal Acquisition Test. An evaluation was made to determine the time required for signal acquisition. The system should automatically acquire LORAN C or D signals even in the presence of random noise and radio frequency interference in areas with satisfactory LORAN coverage. Notch filters are used to mask undesirable frequencies. The system should be out of the search mode and on track in less than 600 seconds even in areas of poor LORAN signal reception.

Propogation Anomaly Tests. The ability of the LORAN navigation set AN/ARN-114 (XE-1) to accept field survey

data of the LORAN grid to correct the UTM coordinates obtained from charts was tested. The propagation points are used to correct for grid warpage due to LORAN anomalies and position offset.

Data Display Tests. An evaluation was made of the system's ability to continuously display the present position. Output in LORAN time differences is calculated with a resolution of .01 usec and UTM coordinates of northing and easting with a resolution of 10 meters.

Range to destination with a resolution of 10 meters is displayed in kilometers. Bearing to destination is displayed to a resolution of 0.1 degrees. Checks on electrical outputs to interface with other avionic equipment and display include course deviation signal and flag signal.

During the flight tests additional data display tests were conducted. Position hold and checkpoint tests were accomplished by overflying predetermined checkpoints and depressing position hold. The receiver position should be accurate in respect to checkpoint position within 130 meters after propagation anomaly corrections are inserted into the system. While in flight the control indicator unit display switch was set to bearing/range, course/ground speed, and crosstrack/distance positions. The displayed data was checked to assure that it correlated with the calculated values.

RESULTS AND DISCUSSION

The performance of the system during the bench test was satisfactory. Proper system displays indicated that installation into the aircraft could proceed. The bench test does not give the operator any indication of the system's ability to acquire LORAN-C signals or radio frequency interference. All LORAN signals are simulated by the test set. Signal reception proved to be a problem during the flight test.

The system accuracy during the first test flight is illustrated in Table 1. The distance from the checkpoint displayed at the moment of overflight ranged from 10 to 320 meters. At only one of the eight checkpoints the system indicated the aircraft was less than 180 meters (the minimum acceptable accuracy limit) from the checkpoint when actual aircraft position was over the checkpoint. The two main reasons for these inaccuracies were: (1) UTM coordinates were obtained from 1:250,000 scale USGS topographic maps; (2) propagation anomaly data was not available for programming the navigation set prior to these tests.

The 1:250,000 acale maps were the only maps available which displayed the two letter identifiers for the 100,000 meter squares necessary for position input data. This scale of map is too small to achieve optimum accuracy

Table I. Navigational Accuracy of LORAN AN/ARN-114 (XE-1) During Flight Test, June 1977.

Checkpoint[1/]	UTM Theoretical	UTM Surveyed	Indicated distance from checkpoint (meters)
1	16 SFN 9580 3620	16 SFN 9560 3607	200
2	16 SFN 3060 2915	16 SFN 29132 1911	2/ —
3	16 SFN 1110 0595	16 SFN 1043 0576	2/ —
4	16 SFM 5205 6690	16 SFM 5170 6680	320
5	16 SFM 7820 6000	16 SFM 7808 5976	10
6	16 SGM 5390 7970	16 SGM 5377 5976	200
7	16 SGN 7540 2960	— 3/	— 3/
8	16 SGN 6300 5075	— 2/	— 2/

1/ Refer to Fig. 3 for geographic location.

2/ System out of track, output data not reliable.

3/ Checkpoint could not be positively identified.

of this navigation system. At the one checkpoint where the larger scale 1:24,000 scale topographic quadrangle map was available, an accuracy of 10 meters from the target position was achieved, i.e., 10 meters from the checkpoint when the system said the aircraft was on target.

Maps at a sufficiently large scale with UTM coordinates and the two letter 100,000-meter square identifiers are needed to obtain the position of selected checkpoints. We have obtained computer programs for the computation of UTM coordinates from geographic coordinates.

As additional overflights of checkpoints are made in different areas of LORAN-C coverage, this data will be available for program input. The checkpoint theoretical value obtained from a map is correlated to the actual surveyed data by the computer to allow increased navigational accuracy.

In order to fine tune the system, time differences at real work positions should be taken each time the aircraft is in flight. This information has been requested by the U.S. Army for use in military training requiring LORAN navigation.

A source of minor error could be mistiming the moment to depress the position hold during overflight of the checkpoint.

Whenever the aircraft engines were below cruising power, such as before departure and on approach to land, the system remained in search without reliable present position displays. The system remained in track only when in flight at cruising power. Possible causes for the out of track status were:

(1) Notch filters need adjustment to filter out known intereferences between 69KH^{z} to 133KH^{z}.

(2) Antenna coupler not grounded properly.

(3) Drop in aircraft power below minimum requirements for system operation.

Eight checkpoints were used in this flight test. Only at four of these could reliable data be obtained. At three checkpoints during the flight test the system was out of track.

Power cables to the panel lights were improperly installed. Therefore, program cuing and advisory status indications could not be obtained.

The course deviation indicator and flag indicator failed to operate throughout the test. This was due to improper installation. Due to the lack of an indication for position left or right of course, the pilot used the indicated bearing and cross track error for navigation. This also decreased navigational accuracy.

The system memory for operator input and navigational data failed to operate. Each time the system power was shut down all operator input data was lost and had to be reprogrammed. A 6.5-volt battery should provide holdup voltage in the event of power fluctuations and during shut down periods. Due to the lack of status advisories, the battery malfunction advisory did not provide an indication of battery failure to the operator.

SUMMARY

Minor equipment malfunctions were discovered during the first preflight and flight test due to improper installation and system power failures. However, work to rectify these malfunctions was initiated after the flight test.

Maps displaying UTM coordinates needed to program the navigation set have not been acquired for the entire Region 8. Only the recently revised editions of the USGS 1:250,000 scale maps provide this information.

The LORAN navigation set has provided accurate navigational information when in track and properly programmed. After the installation faults have been corrected and tested the system should provide a useful, operational navigation aid for a variety of Forest Service applications requiring precision aircraft navigation.

APPENDIX I

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By: Dull, Morris Clerke, Date: July 15, 1977

Installed in: Aero Commander 500B Aircraft Tail No. N194Z

Test	Input or Response	Remarks
Preflight Test		
Input Power AC		
5 VAC Power		-not available in aircraft
Input Power DC		
Voltage 28VDC Power	24.0 to 28.5 VDC 196 watts	
Self Test		
Lamp Segments Illuminate	All segments Illuminate	
Keyboard Illuminates	Keys did not illuminate	-did not provide program cuing -key recognition difficult -no edge lighting
Status Comp OK LOR OK DOP OK	Comp OK LOR OK DOP OK	
		BATMAL was not indicated-as stated in operators manual

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By:_____Date:_____

Installed in:_____Aircraft Tail No._____

Test	Input or Response	Remarks
Course deviation	-CDI-full right indication	-not reliable indication
Indicator left and right	-NAV Flag on OFF -indication intermittent	-incorrect installation of CDI cables: cables to HSI should go to CDI
Present Position Entry	-in suggested sequence to initiate programming	(Clarke 1866)
Spheroid	C6	-only Spheroid entry for North America
Upper Window	16 SGN	-position of aircraft @ PDK
Lower Window	4960 5120	-obtained from 1:250,000 scale USGS Atlanta-Section Topo. Map (1970) (this must be done in UTM Coordinates)

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By:_____Date:_____

Installed In:_____Aircraft Tail No._____

Test	Input or Response	Remarks
Chain Selection Chain	SS7	U.S. East Coast
Select Slave Pair	WZ	-attemped to use WY but would not track
Propagation anomaly	PA-10-24	Data not available -a P.A. Table with 15 points will be constructed with data obtained by field survey-(this data requested by Army)
	CP 99 Check sum	not obtained due to inavailibility of P.A.

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN -114 (XE-1)

Test Conducted By:_____ Date:_____

Installed In:_____ Aircraft Tail No._____

Test	Input or Response	Remarks
Check Point Entry, UTM		All C.P. obtained from 1:250,000 scale Topo. USGS maps-except CP5
0	Present Position	
1	16SFN 9580 3620	Flying S Ranch Grass Strip, Villa Rica, Ga.
2	16SFN 3060 2915	Heflin, Ala. Grass Strip
3	16SFN 1110 0595	Talladega NF Cheaha State Park Lookout Tower Alabama
4	16SFM 5205 6690	Roanoke Alabama Landing Area
5	16SFM 7820 6000	LaGrange, Ga. Waterworks Tank Location obtained from LaGrange Quad. 1:24000 scale

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By:_____ Date:_____

Installed In:_____ Aircraft Tail No._____

Test	Input or Response	Remarks
Check Point Entry (continued)		
6	16 SGM 5390 7970	Griffin Airport
7	16 SGN 7540 2960	Conyers Railroad intersection
8	16 SGN 6300 5075	5 mi off runway for approach
9	Open	
Grid Variation Entry	2.0°E	For magnetic declination @ PDK
Signal Acquisition Time to Track	Did not acquire signal	Maximum signal acquisition time should not exceed 10 minutes

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By:_____ Date:_____

Installed In:_____ Aircraft Tail No._____

Test	Input or Response	Remarks
Data Display Tests		
Present Position -UTM	No accurate display	-system not in track -Function of aircraft location
-Time Difference A	Display not accurate	-not in track
-Time Difference B	Display not accurate	-not in track
-Range, Bearing, CDI, Flag,	-accurate displays were not obtained	-system appeared to remain in search, could not obtain track
From/To	-displayed accurate recall of all input data while aircraft system power on	-memory did not function when aircraft power off

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By:_____Date:_____

Installed in:_____Aircraft Tail No._____

Test	Input or Response	Remarks
Flight Test		
Self Test		
Lamp Segments Illuminate	All segments illuminated	
Keyboard Illuminates	Keys did not illuminate	
Status Computer-OK LORAN-OK DOPPLER-OK	Comp OK LOR OK DOP OK	
Course Deviation Indicator	Needle remained at full right	
LORAN Signal Acquisition		
Time to track	-signal was not acquired until airborne	

ANNOTATED CHECK-OFF LIST FOR TEST OF AN/ARN-114 (XE-1)

Test Conducted By: _____ Date: _____

Installed in: _____ Aircraft Tail No. _____

Test	Input or Response	Remarks
Data Display Tests		
Present position UTM Time Difference A Time Difference B	-same input as in preflight test	-function of aircraft location -display valid only while in flight with cruising speed engine power
Range, Bearing, Course Groundspeed, Cross track Distance	-valid	-while in track during flight-received reliable indications
CDI	-invalid	-full right indication at all times
Flags	-OFF	
Check Points	-same input data as in preflight test	
Upper Display Lower Display	-valid for all checkpoints while in tract	
Position Hold	-functioned properly	-recorded data for all checkpoints after overflight

APPENDIX II

UTM COORDINATES DETERMINATIONS

Grid zone number

$$= 31 + \frac{\text{Longitude}^{o}}{6}$$ truncate to a whole number

East long. - Positive
West long. - Negative
(in Region 8)

Grid zone letter

$$= 13 + \frac{\text{Latitude}^{o}}{8}$$ truncate to a whole number

-- refer to Table I for corresponding letter

100,000 meter square ID. letters

First Letter (Easting)

$$KA = (\text{Zone \#} - 1) - 3K_B$$

where K_B is initially chosen as 0 and successively increased (to a max. of 19) until

$K_A = 0, 1, \text{or } 2$

then:

$$L_1 = 8K_A + \frac{E}{100,000}$$ (meters)

where: E obtained from USGS map (usually a 6 digit no. in Region 8)

- truncate to a whole number
- refer to Table I for corresponding letter

Second letter (Northing)

obtain northing from USGS maps (7 digit number in meters) and refer to Table II

Table I. Look-up Table for Letter Designation.

Letter	Number
A	1
B	2
C	3
D	4
E	5
F	6
G	7
H	8
J	9
K	10
L	11
M	12
N	13
P	14
Q	15
R	16
S	17
T	18
U	19
V	20
W	21
X	22
Y	23
Z	24

Table II. Second Identification Letter for 100,000 Meter Square ID Letter in USFS Region 8.

VALUE OF NORTHING METERS			SPHEROID:CLARKE 1366 ZONE NO.	
			ODD	EVEN
4,000,000	6,000,000	8,000,000		
			K	Q
3,900,000	5,900,000	7,900,000		
			J	P
3,800,000	5,800,000	7,800,000		
			H	N
3,700,000	5,700,000	7,700,000		
			G	M
3,600,000	5,600,000	7,600,000		
			F	L
3,500,000	5,500,000	7,500,000		
			E	K
3,400,000	5,400,000	7,400,000		
			D	J
3,300,000	5,300,000	7,300,000		
			C	H
3,200,000	5,200,000	7,200,000		
			B	G
3,100,000	5,100,000	7,100,000		
			A	F
3,000,000	5,000,000	7,000,000		
			V	E
2,900,000	4,900,000	6,900,000		
			U	D
2,800,000	4,800,000	6,800,000		
			T	C
2,700,000	4,700,000	6,700,000		
			S	B
2,600,000	4,600,000	6,600,000		
			R	A
2,500,000	4,500,000	6,500,000		
			Q	V
2,400,000	4,400,000	6,400,000		
			P	U
2,300,000	4,300,000	6,300,000		
			N	T
2,200,000	4,200,000	6,200,000		
			M	S
2,100,000	4,100,000	6,100,000		
			L	R
2,000,000	4,000,000	6,000,000		

APPENDIX III

LORAN-C, AN/ARN-114 (XE-1) SYSTEM ADJUSTMENTS FOLLOWING INSTALLATION AND INITIAL FLIGHT TESTS

Several system malfunctions due to incorrect installation were discovered during the first flight tests. The following adjustments have been made to rectify these malfunctions:

1. The course deviation indicator and flag indicator were rewired and now work properly.
2. The 6.5 volt battery which provides holdup voltage during power fluctuations and shut down periods was removed and found unable to hold a charge. A new battery was obtained and installed.
3. Power to the panel lights has been properly connected. This allows program cuing and advisory status indications to be observed by the operator. Key recognition is also enhanced.
4. A method to determine UTM coordinates for geographic positions has been developed and is presented in Appendix II. This method is used in conjunction with USGS topographic maps to provide UTM coordinates in the format accepted by the LORAN AN/ARN-114 (XE-1) system. A program has been developed to compute these coordinates.
5. The notch filters may need adjustment in order to decrease the time required to obtain in track status and for the system to remain in track.

The adjustment will require the use of a spectrum analyzer to determine where interference is being encountered. This equipment is not available locally. However, a rental source has been located.

Fine tuning of the LORAN navigation system will continue.

For any additional information, Contact

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